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A NEW TYPE OF MINERAL CLASSIFICATION EQUIPMENT

by

R.P. Charbonnier

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ABSTRACT

A New Type of Mineral Classification Equipment

by R.P. Charbonnier

The Lavodune, recently developed in France and already adopted in a number of size or gravity classification plants in several countries, seems to have great possibilities for the sorting of coal, ores, sands, and many mineral and chemical products. Generally speaking, most ores suitable for gravimetric processing in sizes from 0.5 to 20 mm (in a size ratio of 1 to 8) may be washed at a density of separation from 1 to 4, with an imperfection coefficient of 0.08 to 0.15. Likewise, most pulverulent products of homogeneous densities may be classified at separation diameters between 0.1 and 1 mm, with an imperfection coefficient of 0.12 to 0.25.

The Lavodune is basically an inclined tube, containing an upward flowing liquid. The materials to be processed are fed in at a point halfway along its length. The flow is only sufficient to carry up the finer and lighter particles. The coarser and denser particles sink to the bottom end, where they form a highly turbulent "dune". There, the finer and lighter particles, which may have escaped the initial separation, are reclaimed and taken up again by the rising liquid stream, while the coarse and dense particles continue on their way down. The much greater efficiency of the Lavodune as compared to flow classifiers is obtained by the special profile shape of the inside of the tube. This shape is designed to suit each particular case of separation, by using theoretical considerations but mainly practical experience, obtained in numerous tests with an extensive range of materials.

The main advantages of the Lavodune are its simplicity, absence of moving parts, ease of control, low power requirements, low initial and operating costs, low sensitivity to variations of the feed, low consumption of water (which is recycled), negligible degradation of the material and wear of the equipment. The defects of the Lavodune are minor: relatively low unit capacity and limited range of sizes to be processed. Separation efficiencies may not be quite as high as for some other equipment such as magnetite cyclones, but they are generally satisfactory (better than with the normal equipment) and obtained at much lower costs.

A NEW TYPE OF MINERAL CLASSIFICATION EQUIPMENT

by

R.P. Charbonnier*

INTRODUCTION

In recent years, the Lavodune, a new process of mineral classification, has been developed in France, and adopted in a number of size or gravity separation plants in several countries. This process seems to have attractive possibilities for the sorting of coal, ores, sands, and many mineral or chemical products. It was originally derived from extensive studies on the hydraulic transportation of solids and on the separation of sands from waters, made by Sogreah, which is the engineering subsidiary of Neyrpic, one of the largest manufacturers of hydraulic equipment in the world. The Lavodune classification equipment, which was originally used for the classification of sands and for the cleaning of coals, was developed with the cooperation of Sogreah and the Cerchar research organization of the French national collieries.

Generally speaking, most of the ores suitable for gravimetric processing in sizes from 0.5 to 20 mm (in a size ratio of 1 to 8) may be washed at a "density of separation" from 1 to 4, with an "imperfection coefficient" of 0.08 to 0.15. Likewise, most pulverulent products of homogeneous densities may be classified at separation diameters between 0.1 and 1 mm, with an imperfection of 0.12 to 0.25.

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* Senior Scientific Officer, Fuels & Mining Practice Division, Mines Branch, Department of Mines & Technical Surveys, Ottawa.

As a detailed description of the Lavodune apparatus has been published in the literature[1] in 1958, and more recent results[2] in 1959, the process will not be described in detail in this paper, which is mainly prepared to summarize a number of recent laboratory and industrial results of performances, obtained in the classification of various materials, and also to indicate some new developments based on the Lavodune principles, which will now be briefly analyzed.

SUMMARY OF THE PRINCIPLE OF THE LAVODUNE

The Lavodune should not be confused with processes of the trough or rheolaveur types, which use open ducts with very slight slopes. On the contrary, the Lavodune in its present form uses a completely enclosed duct, steeply inclined (40 to 60°) and containing ascending water currents. It is based on the principle that the "limit velocity of settling" of solid particles, moving by "dune saltation" - approximately according to Rittinger's law[3] - rather than "suspension" - where the motions are mainly of the Stokes' law type (3) -, is practically independent of the particle size and of the concentration of solids in the fluid, provided this concentration is sufficiently high without being prohibitive (e.g. above approximately 100 grams/litre for coal and shales). This velocity depends essentially on the specific gravity of the material that is transported.

Applied in a suitable apparatus, which has been empirically improved, this phenomenon permits the separation of particles having

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(1) Belugou, P., and Condolios, E. "A New Coal-Cleaning Plant: the Lavodune", Paper D4, Third International Coal Preparation Congress, Brussels-Liege, 23-28 June 1958, 10 pp., Institut National de l' Industrie Charbonniere Inichar, Liege, Belgium.

(2) "Un nouvel appareil de lavage: le Lavodune", Echo des Mines et de la Metallurgie, February, 1959, p. 71-72.

(3) Charbonnier, R.P. "A Study of a Simplified Theory of Gravity Concentration in Coal Jigs". Transactions, Vol. 62, Canadian Institute of Mining & Metallurgy, 1959, p. 199.

different densities; for instance the finer and lighter particles such as coal, which will be entrained through the upper end of the tube by the ascending water currents, will be separated from the coarser and denser particles such as the heavier shales or other rocks, which will sink and form in the lower end of the Lavodune a highly turbulent dune, where intermediate and stray particles of coal are rewashed. The heavier particles of this dune are automatically evacuated through the bottom end, when it becomes too large for its own support by the upward water flow. The materials to be processed in the Lavodune are fed in at a point halfway along its length. The much greater efficiency of the Lavodune, as compared to the flow classifiers, is essentially obtained by the special profile shape of the inside of the tube. This shape is designed to suit each particular case of separation, by using theoretical considerations but also, and mainly practical experience, obtained in numerous tests on an extensive range of materials.

PERFORMANCE OF THE LAVODUNE
LABORATORY AND SEMI-INDUSTRIAL TESTS

For coal cleaning, experience (1, 2) has shown that the concentration of solids should not exceed 50 grams/litre in the upper and lower end sections of Lavodune tubes of 92 mm to 500 mm in diameter and 1 to 3 meters in length. Otherwise the dunes become excessively extended along the tubes. In a pilot tube of 92 mm in diameter, about 400 lb/hour of 0.5 - 10 mm Messeix coal have been cleaned at 1.67 partition density d_p with a probable deviation E of 0.075 and an imperfection $I = E/(d_p - 1)$ close to 0.11. For sizes below 1.6 mm

(about 12 mesh), d_p, E and I quickly increased up to values in the order of d_p = 2.2, E = 0.38 and I = 0.32 for the minus 1 mm coal. Below 0.5 mm, there was no longer any significant separation.

For ore concentration, laboratory tests (2) have given the following results with a 92 mm tube: for 0.5 - 1.3 mm ores of uranium, diamonds and barytes, concentrated at a d_p of 2.7 to 3, the imperfection I was approximately 0.08.

In semi-industrial tests, using a tube of 250 mm, about 4 tons/hr of 1-8 mm coal have been cleaned at a partition density d_p = 1.9 with an imperfection I ranging from 0.14 to 0.18.

For the size classification of sands (which was one of the earliest applications of the Lavodune process, in connection with the extensive sand models of harbours, rivers, dams, etc., at the Sogreah laboratories), when using a tube of 300 mm, about 1.5 t/hr of 50-500 micron sand have been separated at a 135 micron cut, and the imperfection, i.e. the ratio of E to the value of the separation cut, was about 0.2, which was better than had been obtained with cyclones, sievebends, etc.

INDUSTRIAL RESULTS

An industrial coal cleaning plant of the Lavodune type has been installed(4) at the Somain mine of the National French Collieries of the North. A first series of tests was conducted on 2-4 mm coal, cleaned in Lavodunes of 250 mm diameter. The ash content varied from 15 to 34% for the raw coal, from 5.8 to 13.5% for the clean coal, and from 64 to 81% for the refuse. The yield in clean coal ranged from 84 to 96%, and the separation density from 1.6 to 2.3. The overall imperf-

(4) Chevallier, A. "Essais de lavage de charbon par Lavodune de 250 mm a Somain (H.B.N.P.C.)" R.7.107, Sogreah, Grenoble, France, March 1959.

ection was found to range between 0.7 and 0.13.

The second series of tests was carried out on 1 - 8 mm coal in the same Lavodune plant after some modifications were made, especially in the feeding of the raw coal and the water. Then the ash content varied from 6.4 to 13.4% for the clean coal, and from 70 to 83% for the refuse. The yield in clean coal varied from 79 to 86%, and the separation density d_p from 1.7 to 2.1.

The overall imperfection I was estimated between 0.17 and 0.23, while the average probable deviation E_m was in the range of 0.12 to 0.22.

The influence of the particle size may be seen on Table 1. It has been found desirable to clean narrow sizing fractions separately, rather than a wide range of sizes together in the same Lavodune tube.

TABLE 1

Influence of the Particle Size on the Performance of the Lavodune

Size mm	Ash %			Yield % (clean)	d_p	E_m	I
	Raw	Clean	Refuse				
1.25-3	14.0	8.2	71.1	87.3	1.92	0.19	0.21
3-5	13.7	5.7	71.3	86.2	1.82	0.16	0.19
5-8	17.5	5.3	74.2	81.8	1.71	0.09	0.12
1-8	18.4	7.9	70.4	85.8	1.88	0.20	0.23

In addition to this industrial Lavodune plant at Somain, there are at present another Lavodune coal washery at the Tamaris coal mine in the Cevennes Collieries of Southern France, and a larger coal washery using 6 Lavodune tubes of 425 mm in diameter at Freyming in the Lorraine Collieries, where all the coal fed into the Huchet coal-in-water pipeline is to be cleaned by Lavodune equipment. This Lavodune installation now cleans about 150 t/hr of minus 1mm coals in a water flow of approximately 1000 t/hr. Some size separation occurs and the larger particles of coal are recovered from the heavier fine particles of shales by wet screening. The performance results are reported as excellent.

In a diamond mine of the Ivory Coast of Africa, about 30 tons/hr of diamond bearing gravel sands are processed in 32 Lavodune units of 100 to 250 mm in diameters.

As a sizing classifier, the Lavodune seems to be very satisfactory for dimensions as low as 0.8 to 0.9 mm of various materials, such as barytes, manganese, feldspars, dolomites (for example in a 1 ton/hr plant near Paris), sands (for instance in a 5 ton/hr plant in Drome, featuring 3 separation cuts: 0.2, 0.4 and 0.6 mm). Below 0.5 mm there seems to be no significant size separation for coal, although a size classification of homogeneous materials seems possible above 0.1 mm.

MOST RECENT RESULTS

In recent pilot plant tests on manganese ores, the following results have been obtained on the four sizes: 0.5 - 2 mm, 3-4 mm, 4-10 mm and 10-20 mm: for the preparation of metallurgical concentrates, the partition density d_p varied from 2.75 to 3.25, and the imperfection achieved was in the range of 0.11 to 0.25. For the preparation of chemical concentrates (with 80 to 85% of MnO_2), d_p exceeded 4. Table 2 shows an example of the results obtained.

TABLE 2

Pilot-plant Lavodune Classification of Manganese Ores

Size mm	Manganese Content %			Yield % in metal	d_p	I
	Feed	Light ends	Heavy ends			
2-4	48.8	40.5	51.9	82	2.97	0.13
4-10	52	42	53.8	88	2.75	0.16

The laboratory and pilot plant results have later been satisfactorily confirmed by semi-industrial tests: the metallurgical concentrates (with 48 to 50% of Manganese and even higher contents) were easily produced with partition densities varying from 2.55 to 3.24, according to the Mn contents of the raw ore and of the desired concentrates. For the chemical concentrates, the results of two typical tests are given in Table 3.

TABLE 3

Semi-industrial Lavodune Classification of Manganese Ores

Size mm	Manganese content in MnO_2 %		
	Feed	Light ends	Heavy ends
0.5-2	72.9	72.3	82.2
3-5	66.1	64.7	80.6

In the C.D.M. pilot plant installation, in Western South Africa, where 5 tons/hr of diamond bearing sands are classified in a double series of Lavodunes with recycling of the tailings from the second series, the efficiency of the separation, as shown in the control of losses estimated by diamond radioactivity, has been maintained above 95%.

A new Lavodune plant for the size classification of sands has recently been installed at the sand and gravel pits of Weiach, where 60 tons/hr of sands are classified at three sizing cuts: 0.02 mm, 0.2 mm and 1 mm with excellent results.

COSTS

The capital costs of a Lavodune plant, including plant construction, which originally was about $2,000 per ton/hr of capacity, has been recently reduced to around $1,200 per ton/hr. This compares favourably with the costs of jigs, rheolaveurs and cyclones. The operating costs are very low because of the simplicity of the Lavodune process.

LATEST DEVELOPMENTS

The capacity of Lavodune unit has recently been increased to 60 tons/hr for the size classification of sands, and to 40-45 tons/hr for the processing of manganese ores. However, it is easy to design units offering even larger capacities.

The settling ratio depends mainly on the material being processed, and on the separation requirements. It may be in the order of 2 or 3 (e.g. for diamond bearing sands, or for manganese ores), but it may also reach 8 or even 12 in some cases (e.g. for the gravity separation of gravels mixed with a high proportion of lighter materials, wood or others).

NEW APPARATUS

A new hydraulic classification process is at present undergoing a series of tests at the Sogreah-Neyrpic research laboratories. Although this new apparatus looks very much like the Lavodune, it is based on a different principle (fluidized bed), and its operating conditions significantly differ from those of the Lavodune, chiefly on the following points: the concentration of solids is higher (100 grams/litre and over) than in the Lavodune. It is used for the classification of materials finer than 1 mm, and gives optimum performances with a feed size of 0.08 - 0.5 mm. Some tests on heavy materials (such as iron

ores like magnetites) have shown that the separation is still excellent on 40 micron particles. The capacity of the one-cell research unit varies from 100 to 200 kilograms/hr depending on the material being processed. A pilot plant multi-cell unit has now been built, and its capacity is 0.5 to 1 ton/hr. No serious difficulties are expected in the design of units of 10 tons/hr capacity.

A number of materials have now been tested, such as ilmenite-bearing beach sands, iron ores, etc. For example, Table 4 shows typical results obtained on an iron ore from Lorraine, in which the pure oolithe contained 52 to 53% of iron, while the cement consisted of mixed iron silicates (thus keeping relatively high the iron content of the refuse).

TABLE 4

Results of Classification of a Lorraine Iron Ore

	Weight %	Iron Content %	Metal Yield %
1. Concentrate	19.8	49	
Refuse	80.2	28.4	30
Feed	100	32.5	
2. Concentrate	46.5	42.2	59.5
Refuse	53.5	25.2	
Feed	100	33.1	

CONCLUSION

The main advantages of the Lavodune process are: its simplicity, absence of moving parts, easiness of maintenance and control (only one important factor: the water supply). Other qualities are: low power requirements, low initial and operating costs, low sensitiv-

ity to variations in the feed, low consumption of water (which is recycled), negligible degradation of the material and wear of the equipment, feasibility of direct treatment of slurries.

The defects of the Lavodune seem to be minor: relatively low unit capacity and limited range of sizes to be processed (which may require preliminary size separations). The reduction of the lower size limit of effective separation seems now solved by the development of the latest type of apparatus mentioned in this paper.

With reference to coal cleaning efficiency, the Lavodune process may be compared to the more expensive filter bed jigs, so frequently adopted for the 1-10 mm coals, and giving imperfections I ranging from 0.1 to 0.2. For the 0.5 - 1 mm fraction, the imperfection is likely to increase by 25%. For 0.3 mm, the imperfection increase usually exceeds 70%. In rheolaveurs, cleaning 0.5 - 10 mm coals, the imperfection may range from 0.12 to 0.20, and higher for the 0.5 - 1 mm fraction. In magnetite cyclones, cleaning 0.8 - 10 mm coals, the imperfection is usually in the order of 0.04 to 0.10, and even for the fraction 0.2 - 0.8 mm, I is usually about 0.15 - with higher d_p (e.g. around 2.15 instead of 1.75 for the coarser coals). However, in addition to their special additional costs for magnetite circuits and auxiliary equipment, these cyclones may cause too much degradation of the coal sizing in some plants.

Generally the operating costs may be twice as high (e.g. 25 cents/ton of raw coal) for the magnetite cyclone as for the jigs or rheolaveurs. The fixed costs seem also to be frequently about twice as high for magnetite cyclones as for jigs, which generally are already more expensive than the Lavodune.

Thus, it appears that the Lavodune process may have a promising future in coal cleaning plants for the 1 - 10 mm coals, and maybe even brighter possibilities for gravity or size classification of ores or chemical products. The potentialities of application of this equipment in Canadian mines, quarries and other industries should therefore be carefully considered.

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